

GEOMORPHOLOGY OF DEBRIS APRONS IN THE EASTERN HELLAS REGION OF MARS.

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Recent geologic mapping and geomorphic analyses [1-4] have documented the geologic history of the eastern Hellas region of Mars in terms of the styles, timing, and evolution of volcanic activity associated with eruptive centers at Hadriaca and Tyrrhena Paterae. As a result of the geologic relationships between regional volcanic units and the Dao, Harmakhis and Reull Valles outflow channel systems, constraints have been established for the timing and nature of erosional and depositional processes occurring in the region [1-8]. The present study examines late-stage (Amazonian) degradation processes recorded in a series of debris aprons and debris flows located predominantly around massifs in the eroded southern highlands along the Reull and Harmakhis Valles outflow systems.

Morphologic Characteristics of Debris Aprons

Viking Orbiter images and a recent detailed geologic map [6] of part of the eastern Hellas region were examined to locate and characterize debris aprons and debris flows [1,5]. Earlier studies indicate that these features are not found in other circum-Hellas regions [5]. Fifty six of these features are identified in the region between 30° - 47.5° S and 245° - 270° W, southeast of Hadriaca and Tyrrhena Paterae and south of Hesperia Planum. Specifically, debris aprons are distributed within two prominent intersecting zones: 1) adjacent to and along Reull Vallis and at the intersection of Harmakhis and Reull Valles; and 2) in a northwest to southeast trending zone starting near the northern end of Reull Vallis and extending across the heavily cratered highlands to the northwest [6].

Two types of deposits are observed that are distinguished on the basis of their occurrence in either crater interiors or adjacent to isolated or clustered highland massifs (Table 1) [5-6]. Debris aprons located in crater interiors are typically confined by crater rims, exhibit mottled albedoes, have relatively featureless surfaces, have smaller areal extents than massif-associated aprons, and have both arcuate and lobate frontal morphologies. Debris aprons associated with highland massifs have uniform or mottled albedoes [5-6], have lobate frontal morphologies often with steep scarps, occur in groups around an individual massif, and may exhibit lineations on their upper surfaces parallel to their apparent direction of motion [1,5-6]. In many cases, this type of debris deposit surrounds its associated massif (or clustered massifs) on all sides. Irregularities in the lobate fronts of debris deposits associated with massifs appear to be related to the shape of the associated massif and/or multiple lobe deposition.

Surface characteristics of debris aprons can be used to make inferences regarding their depositional mechanisms and subsequent modification processes. A characteristic lobate debris apron (38.8° S, 262° W) north of Reull Vallis has an elongate flow-like morphology and exhibits low ridges both parallel and perpendicular to its apparent flow direction [1]. This pattern of ridges is also found on terrestrial rock glaciers where ridges perpendicular to the direction of motion are attributed to compression caused by a decrease in flow velocity, whereas ridges parallel to the flow direction result

from internal shear [9]. In addition, a large debris apron (46° S, 250° W, see detailed description below) surrounding a massif south of Reull Vallis has multiple lobes with parallel and perpendicular ridge patterns, some of which are terminated at various lobe margins and others which extend across adjacent lobes. In the fretted terrain of the northern plains of Mars, lineated valley fill and concentric crater fill with similar morphologic characteristics have been interpreted to result from movement of surface materials facilitated by the creep of interstitial ice [10-13].

An evaluation of debris apron stratigraphic positions, based on recent geologic mapping of the region [6], indicates that the debris aprons are locally among the youngest features. Correlations with geologic units [6, 14] illustrate that debris deposits are located on Noachian, Hesperian, and Amazonian materials (Table 1); previous regional mapping demonstrates that debris aprons are younger than the channeled plains rim unit and channel floor materials near the source region of Harmakhis Vallis [1]. Two large debris aprons (39.5° S, 264.5° W and 39° S, 265° W) have been identified that appear to fill portions of both Reull and Harmakhis Valles. Several individual debris aprons cover multiple geologic units with diverse ages. Adjacent to the pitted plains unit, several debris aprons exhibit surface morphologies similar to the plains, with characteristic pitted surfaces extending onto debris aprons in an apparently continuous style, perhaps indicating a similar depositional mechanism or type of post-emplacement modification.

Geomorphology of Debris Apron at 46° S, 250° W

A detailed geomorphic analysis of Viking Orbiter images of a large massif-associated debris apron located south of Reull Vallis reveals numerous flow features, multiple failure events and associated fluvial erosive processes. Specifically, the ~ 40 km long debris apron almost completely surrounds its parent massif and includes compressional ridges, multiple slump blocks within the apron and on the massif scarp, pitted and banded surfaces, erosional spur and gully failure scarps, a moat at the contact between the debris apron and the massif, and surface drainage channels. The northern and western facing portions of the debris apron consist of multiple debris lobes with erosional channels formed at apparent surface junctions between lobes. The debris apron surface at this location also includes ridges and banding which are discontinuous between adjacent lobes. In this region, there appear to be several breaches of the moat; erosional gullies extend from the massif/apron contact through the apron onto the underlying geologic units. In some regions of the apron it appears that these channels coalesced and, once off the apron surface, flowed southward along the frontal lobes of the apron perhaps accentuating the observed scarps in this area. The portion of the debris apron extending to the southern side of the massif consists of a large lobate deposit with pronounced pitting and continuous ridges and banding, perhaps indicating emplacement as a single lobe. This portion also exhibits moating and surface erosional channels. Toward the toe of the apron, there is a

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pronounced scarp parallel to the lobe front but facing towards the massif; this scarp creates the appearance that the deposit lost volume or deflated at some point during deposition. The nature of the parent massif on the south side is not discernible due to shadowing.

Conclusions

The geomorphologic properties of debris aprons in the eastern Hellas region suggest that they formed due to slope instabilities primarily on highland massifs adjacent to outflow channels. The close association and uniform distribution of these materials around highland massifs and the lack of any preferential orientation of deposits in the region indicates that these features are locally derived and are not consistent with a primary aeolian origin or formation by direct deposition of material flowing across the surface from another region [5]. The surface characteristics and erosional features imply that the emplacement of these debris aprons and flows may have been partially fluidized, presumably due to local ground ice or water. Specifically, debris morphologies reveal multi-stage emplacement processes and complex post-emplacement modification dominated by fluvial processes. Additional detailed analyses of debris apron morphology, emplacement history, modification processes and age relationships will provide constraints on the nature and distribution of volatiles in the eastern Hellas region and documentation of Amazonian degradational styles in the Martian highlands.

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TABLE 1.

Location	Underlying Unit*	Front Morphology	Occurrence
33.8°S, 259.3°W	Nh ₁	lobate	massifs
33.7°S, 254.5°W	pd	lobate	massif
33.5°S, 256.5°W	pd	lobate	crater ejecta
33.2°S, 257.8°W	pd	lobate	massif
33.0°S, 258.0°W	pd	lobate	crater interior
34.7°S, 253.5°W	pd	lobate	massif
34.5°S, 256.0°W	pd	lobate	massif
34.5°S, 255.8°W	pd	lobate	massif
35.8°S, 257.7°W	Nh ₁	lobate	crater interior
36.6°S, 256.4°W	pd	lobate	crater ejecta
37.2°S, 258.5°W	pd	lobate	massif
37.0°S, 265.0°W	AHh ₅	lobate	massif
37.3°S, 255.9°W	pd	lobate	massif
37.6°S, 266.0°W	AHh ₅	lobate	massif
37.5°S, 255.7°W	pd	lobate	massif
37.5°S, 255.3°W	pd	lobate	massif
37.5°S, 250.8°W	Nh ₁	lobate	massif
37.8°S, 250.3°W	ps ₁	lobate	massif
38.2°S, 253.5°W	ps ₁	lobate	massif
38.5°S, 256.7°W	Nh ₁	arcuate	crater interior
38.8°S, 265.0°W	AHv	lobate	massif
38.8°S, 262.0°W	AHpp/Nh ₁	lobate	massif
38.7°S, 256.4°W	ps ₃	lobate	massif
38.5°S, 251.3°W	Nh ₁	arcuate	crater interior
39.0°S, 256.5°W	ps ₃	lobate	massif
39.5°S, 264.0°W	AHv/AHpp/AHh ₅	lobate	massif
39.5°S, 256.0°W	Nh ₁	arcuate	crater interior
40.0°S, 257.0°W	ps ₃	lobate	massif
39.5°S, 253.5°W	Nh ₁	arcuate	crater interior
40.0°S, 255.8°W	Nh ₁	arcuate	crater interior
39.5°S, 252.3°W	Nh ₁	lobate	massif
39.3°S, 249.2°W	Nh ₁	arcuate	crater interior
40.0°S, 251.5°W	Nh ₁	lobate	massif
40.5°S, 252.5°W	Nh ₁	lobate	massif
41.0°S, 257.0°W	ps ₃	lobate	massif
40.7°S, 247.0°W	Nh ₁	lobate	massif
41.4°S, 254.1°W	Nh ₁	arcuate	crater interior
42.0°S, 256.0°W	ps ₃	lobate	massif
41.3°S, 257.5°W	ps ₃	lobate	massif
41.4°S, 251.0°W	ps ₃	lobate	massif
42.0°S, 254.8°W	AHv/ps ₃	lobate	massif
42.0°S, 251.0°W	ps ₃	lobate	massif
41.5°S, 245.4°W	pd	lobate	massif
43.5°S, 263.0°W	AHh ₅	lobate	massif
43.0°S, 252.0°W	ps ₃	lobate	massif
42.8°S, 251.5°W	ps ₃	lobate	massif
42.8°S, 250.0°W	pd	lobate	massif
44.3°S, 250.8°W	AHh ₅	lobate	crater interior
44.0°S, 245.2°W	Nh ₁	lobate	crater interior
45.0°S, 255.0°W	AHh ₅ / ps ₃	lobate	massif
45.5°S, 268.5°W	AHh ₅	lobate	crater interior
45.6°S, 248.5°W	pm	lobate	massif
45.0°S, 245.3°W	pm	lobate	massif
46.5°S, 253.8°W	AHh ₅	lobate	massifs
47.0°S, 248.0°W	pm/Nh ₁	lobate	massifs
47.3°S, 259.0°W	AHh ₅	lobate	massifs

* Units are from Mest and Crown, 1997 (see reference [6]).